Space Weather Technical Forecast

Issued on Sunday, 26 November 2023 at 13:07 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Isolated M-class flares/R1-R2 Radio Blackouts likely throughout. Chance of G1 Geomagnetic Storms Days 1-2 (25-26 Nov).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low, with a peak C4.4 flare at 25/1440 UTC from AR3503 close to the Eastern limb. There are eleven sunspot regions currently on the visible disc. Near centre disc in the northern hemisphere there is a cluster of four sunspot regions that appear to be contained within the same area of plage and connected magnetically. AR3492 (Hax/Alpha) is the largest group within the region and consists of two large unipolar spots, with trailing opposite polarity spots now faded. AR3490 (Dao/Beta) in the north of the group has simplified slightly, but has seen some recent flare activity. AR3502 (Dao/Beta) and AR3491 (Axx/Alpha) to the south of AR3492 remain largely unchanged.

The largest group currently on the disc is AR3500 (Dkc/Beta-Gamma-Delta) in the southeast. This compact region primarily consists of a large delta spot and other mature spots in close proximity. AR3499 (Dai/Beta) in the southwest has seen some slight growth. AR3499 (Dai/Beta) in the southwest has seen some slight growth and recent flare activity.

The other groups on the disc are smaller and more magnetically simple than the previously mentioned regions.

No Earth-directed CMEs have been observed in the past 24hrs.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by ACE and DSCOVR at L1, have been Elevated, staying mostly steady around 520-550 km/s since the arrival of a CME that left the Sun on 22 Nov, as well as the possible connection to CH75/+. The solar winds briefly became Strong, peaking at 626 km/s at 25/2152 UTC. Solar wind density has been above average, with a peak of 24 pccc at 25/1711 UTC. The Interplanetary Magnetic Field (IMF), Bt, was initially Moderate following the CME arrival, peaking at 13 nT, before a slow but steady decline has been observed since. The IMF is currently at Weak levels, around 6 nT. The important north-south component, Bz, was predominantly negative upon the CME arrival, but did vary between +11 nT and -11 nT. Since 25/2100 UTC it has varied weakly between +5 nT and -6 nT. Phi angle was initially fairly neutral, but since 25/1400 UTC has been consistently positive (away from the Sun). The resultant geomagnetic activity was initially at G1/Minor Storm levels (Kp5), increasing to G2/Moderate Storm levels (Kp6) between 25/1800-2100 UTC, before decreasing to Unsettled (Kp4) after that. It has since dropped slightly further to Unsettle levels (Kp3) since 26/0300 UTC.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at Background levels. GOES16 high energy (greater than 2MeV) electron flux has been at Background levels throughout the period. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu) on a gradually declining trend. The fluence

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observation at 26/0000 UTC was 1.95e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be Moderate with isolated M-class flares (R1-R2, Minor-Moderate) likely and a slight chance of an isolated X-class (R3-Strong) flare. The main flare risk is from regions currently positioned on the eastern solar hemisphere and those in the cluster close to the centre of the disc in the north.

Solar Wind / Geomagnetic Activity: Two possible CMEs feature in the forecast. Firstly, the southwards directed CME observed from late 22 Nov, which may have already arrived, and secondly, the CME that resulted from the M1.1 flare from AR3499 on 24 Nov, which has been modelled as a slight chance of a glancing blow on Day 2 (27 Nov).

Solar winds are currently enhanced following the recent CME arrival(s) and are at Elevated levels, between 500-550 km/s. There is some uncertainty if these elevated wind speeds are currently due to connection with a HSS from CH75/+ or due to lingering enhancement from the earlier CME arrival. It is probable that the Earth is connected to the HSS, and so solar winds are forecast to remain at, or close to, Elevated levels through Days 1-2 (26-27 Nov). With the uncertainty in CME arrivals during these days, there remains the possibility for winds to increase, perhaps to Strong levels (600 km/s) at times. As such, there is significant uncertainty in the short term forecast. Solar winds are expected to drop back to more Ambient levels from Day 3 (28 Nov) onwards, as CME and HSS effects ease.

Geomagnetic activity is currently Quiet/Unsettled (Kp2-3), and will likely remain similar through Days 1-2 under the influence of the HSS, with Active intervals likely. If any of the CMEs mentioned do arrive on Days 1-2 then there is a chance for G1/Minor Storm intervals (Kp5), as well as a slight chance for G2/Moderate Storm intervals (Kp6), as these CME effects combine with the HSS. From Day 3 (28 Nov) onwards, geomagnetic activity is expected to fall back to mostly Quiet levels (Kp1-2).

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain at Background levels. However, there is a slightly higher risk of observing S1/Minor Storm conditions compared to normal, given the number of sunspots currently on the disc and their propensity to move into a more favourable location on the disc for connection with Earth in the coming days.

Electron flux levels are at Background levels following the arrival of the CME from early 22 Nov. Similarly suppressed flux levels are expected over the coming days given forecast combined CME and high-speed stream influence on geomagnetic activity. High levels of election flux are unlikely to be reached until Days 3-4 (28-29 Nov) when there is an increasing chance that the reduction in the solar wind pressure following the CMEs and high-speed streams could allow electron flux to subsequently increase.

Fluence levels are expected to remain below the 1e8 Active threshold throughout the period with any notable rise not expected to take place until Day 3 (28 Nov) or later.

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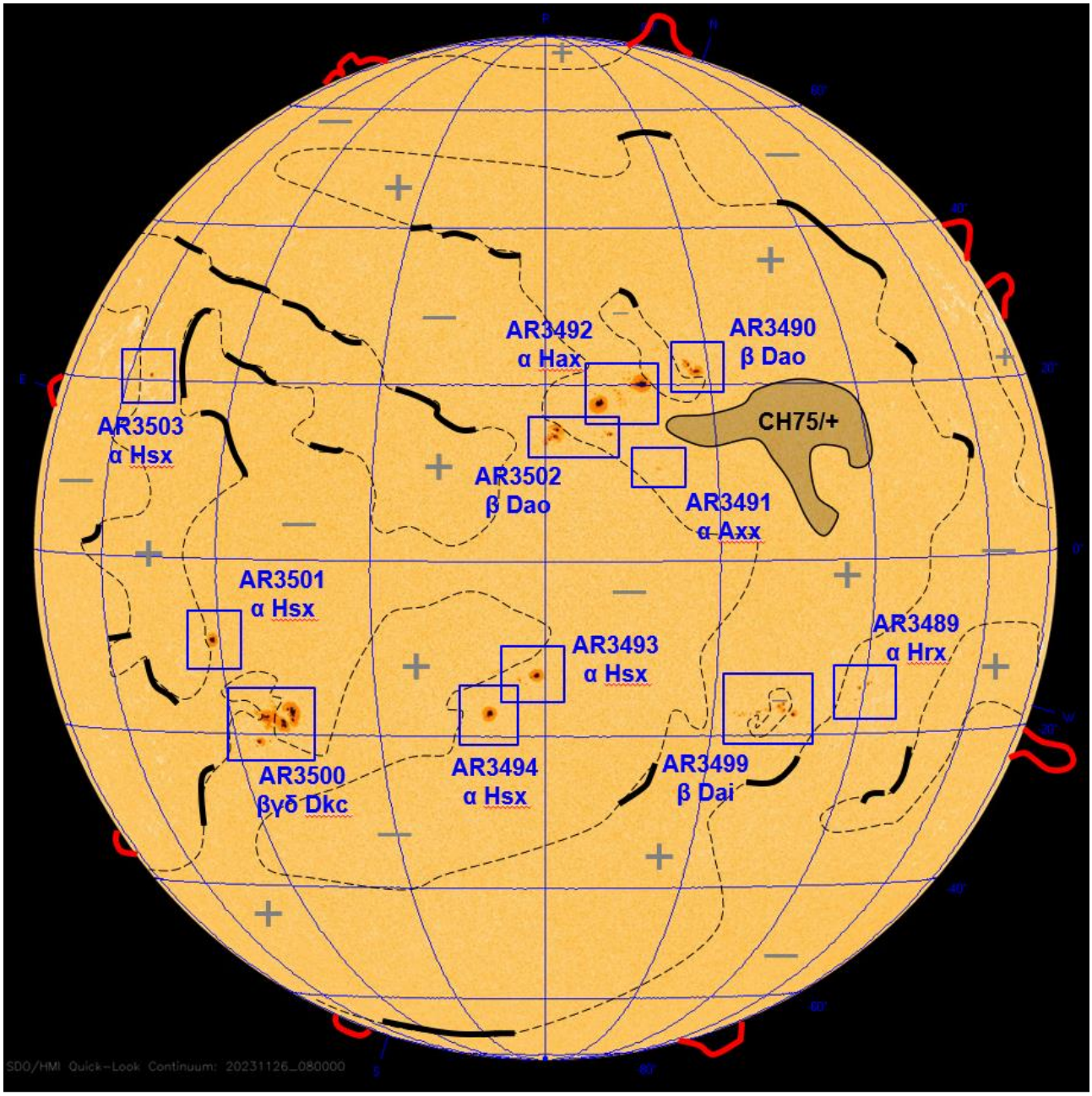
Figure 1. Solar Analysis Valid 26/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:
No Earth-directed CMEs have been observed leaving the Sun in the past 24hrs.

The Earth is currently under the possible influence of two CMEs and a HSS. The two CMEs both lifted off from the Suns surface on 22 Nov, the first from a filament eruption in the southeastern quadrant, and the second a partial halo CME from later 22 Nov that was directed southwards. The second CME was initially analysed to arrive sometime early on 26 Nov (Day 1), but may have arrived earlier than anticipated on 25 Nov shortly after the first CME arrival, as a double jump in solar wind speeds and magnetic field strength at earth was observed. This conclusion is only moderate confidence currently, with the second CME still possibly yet to arrive at Earth, although it is only expected to be a glancing blow.

A third CME is in the forecast and is associated with the 24/0933 UTC M1.1 flare from AR3499 in the southwest quadrant of the disc. This has been analysed and modelled as a likely miss below Earth's orbit with just a slight chance of a glancing blow during Day 2 (27 Nov).
Solar winds are have been at Elevated levels around 520-550 km/s since the arrival of the CME early on 25 Nov. There is some uncertainty if these continued elevated wind speeds are due to connection with a HSS from CH75/+ or due to lingering enhancement from the CME arrival(s). If the current elevated levels are due to connection with the coronal hole, then this connection has occurred earlier than anticipated. On the previous rotation, this coronal hole was a much larger and darker feature than it appears currently on imagery and resulted in speeds of 570km/s and a period of several days at elevated levels. This may possibly occur again, although with the winter solstice approaching this will likely be weaker than the previous rotation. Solar winds have remained consistently at Elevated levels, and although there has a been a small reduction in wind speeds since 26/1100 UTC, it is still probable that the Earth is currently in this HSS. Solar winds are therefore forecast to remain at, or close to, Elevated levels over Days 1-2 (26-27 Nov), before a steady decline back to ambient wind speeds. There does remain that element of uncertainty regarding the current positioning of the HSS, as well as any further CME enhancements over Days 1-2 as mentioned, which could see a rise in solar winds speeds, perhaps to Strong levels.

Geomagnetic activity is currently at Quiet/Unsettled levels (Kp2-3). With no further CME arrivals then this is expected to remain similar for Days 1-2 (26-27 Nov), with the chance of some Active periods (Kp4). However with the uncertainty regarding any CME arrival on Day 1, and a possible CME glancing blow on Day 2, there does remain a risk of further enhanced geomagnetic activity during this period. On Day 1 there remains a chance for G1/Minor Storm levels (Kp5), with a slight chance of G2/Moderate Storm intervals (Kp6), due to the combination of any CME arrival and HSS effects. A slight chance of seeing G1/Minor Storm intervals is also possible on Day 2 in association with the glancing blow CME. A decline from Day 3 (28 Nov) would then be expected as CME influences and solar winds ease, with geomagnetic activity forecast to become Quiet (Kp1-2).

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Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	50	20	2	1
Strong	G3	No	10	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
23/0535	Partial	Filament Eruption	SE (near AR3489)	540 km/s	26/0000 UTC	May have arrived early on 25 Nov, but low confidence.
24/1707	Partial	Filament Eruption	S central disc	522 km/s	27/1200 UTC	Slight chance of glancing blow.

Figure 2: MOSWOC Enlil model and ensemble runs to show possible CME and HSS arrivals.

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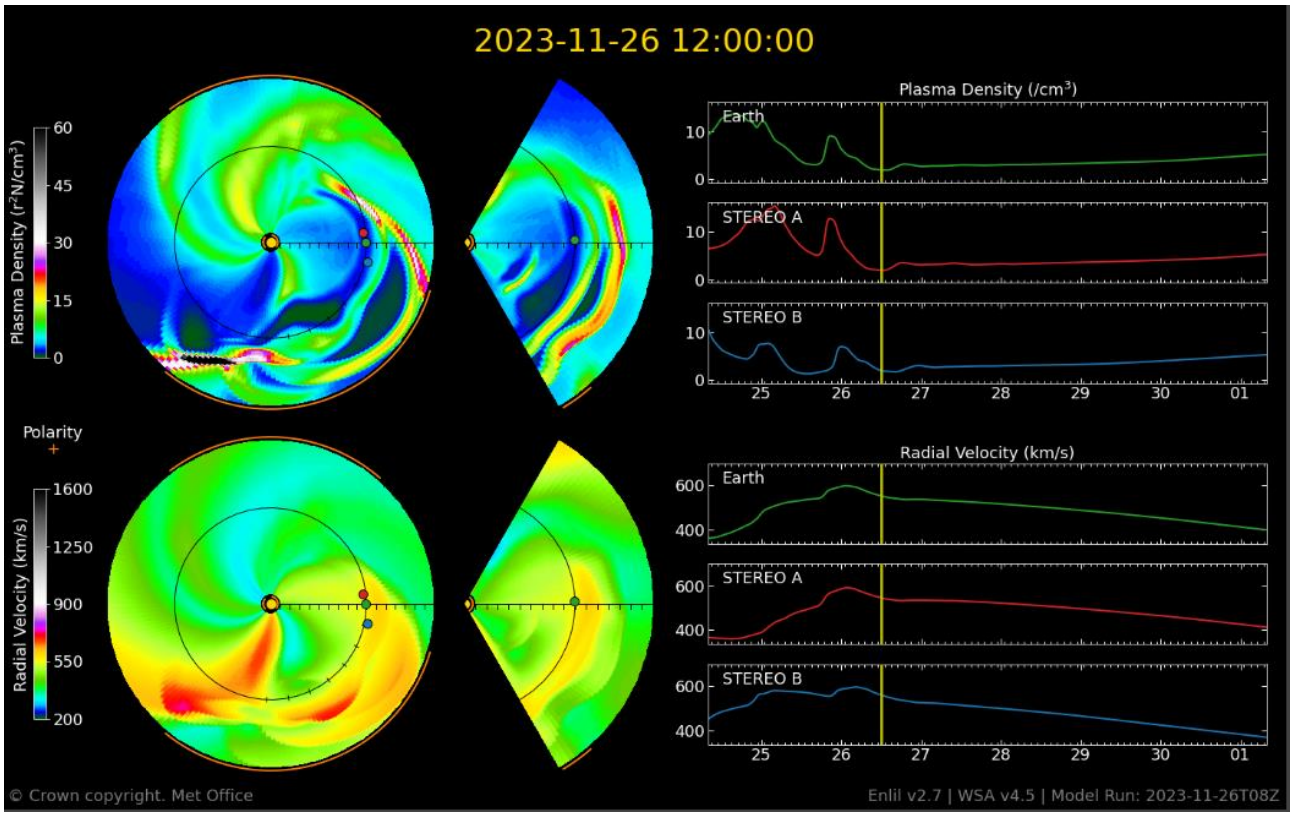

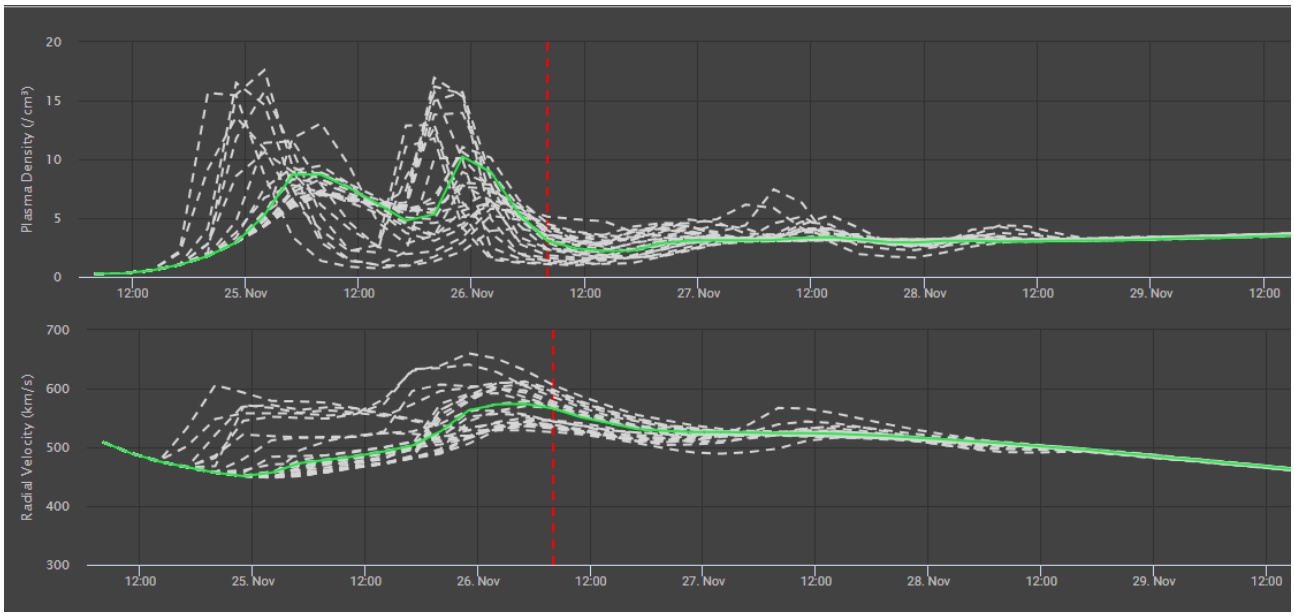

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Radio Blackouts - X-Ray Flares:
There are eleven sunspot regions currently on the visible disc.

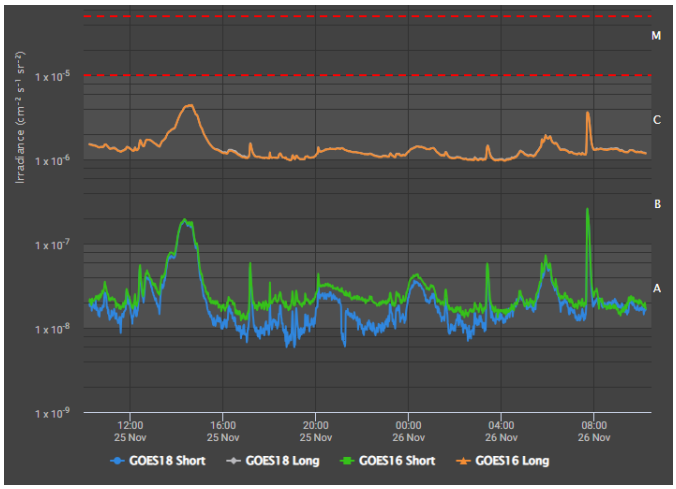
There are a few notable regions worth keeping an eye on over the coming days. AR3500 (Dkc/Beta-Gamma-Delta) in the southeast is the largest region on the disc, with some magnetic complexity of its central spot giving it a delta configuration. No flare activity has been observed as of yet, but it is one to keep monitoring. Near centre disc in the northern hemisphere is a cluster of four sunspot regions, and whilst they are mostly all fairly simple, the proximity to each other and the fact they are all in the same plage region, means this region could provide some further activity over coming days. AR3499 (Dai/Beta) in the southwest has also seen some slight growth recently, with trailing and intermediate spots waxing and waning over the past 12hrs.

The other groups on the disc are smaller and more magnetically simple than the previously mentioned regions.

Bright areas on SDO imagery and occasional CME activity just beyond the eastern limb suggests the presence of further active regions that are expected to rotate onto the visible disc by Day 4 (29 Nov). As a result, flare probabilities have been maintained at relatively saturated levels. Activity is expected to increase to Moderate, with isolated M-class flares, and a slight chance of an isolated X-class flare.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	60	60	60	60
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: GOES 16 & 18 X-ray flux



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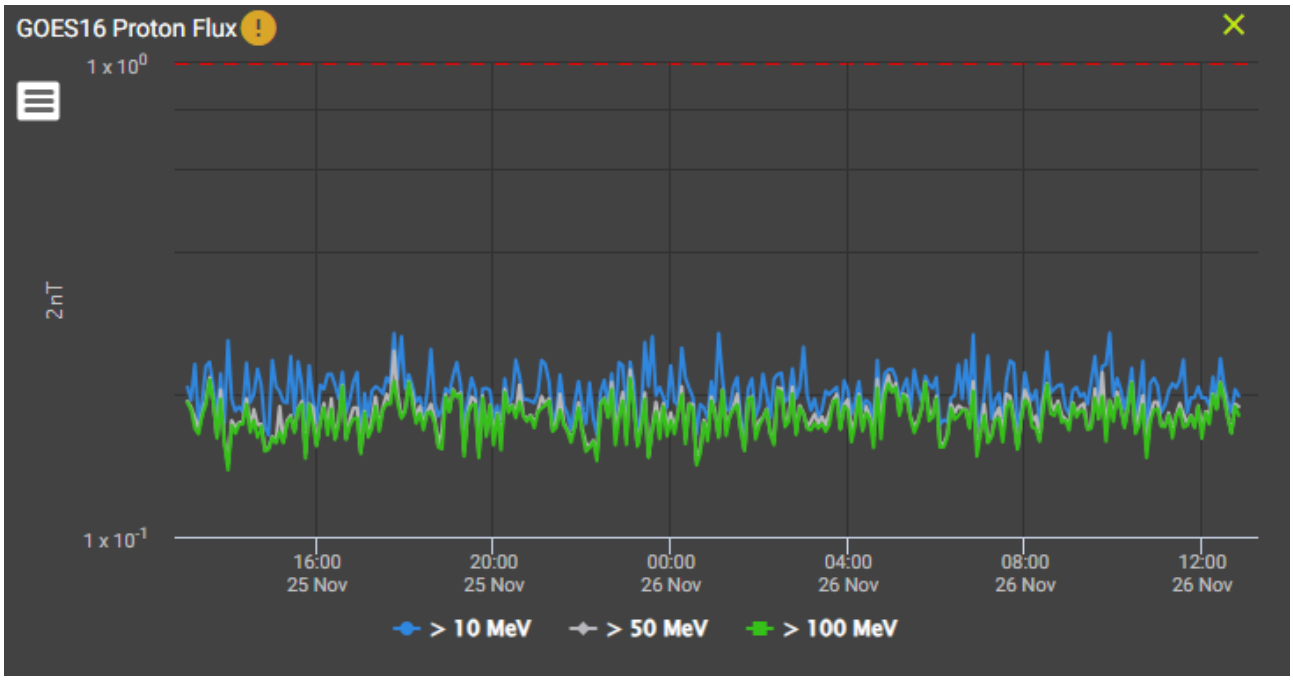
Solar Radiation Storms - (High Energy Protons):
The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at Background levels.

There are several moderately-large and fairly complex regions close to the centre of the disc in the northern hemisphere. These result in a slightly above background risk of an S1/Minor Solar Radiation Storm in the coming days. This risk remains small, but with a minor uptick in probabilities from Day 2 (27 Nov) when these groups move into a more favourable location for connection with Earth, as they move further into the western solar hemisphere, apparent from Earth.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	15	15	15
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES 16 Proton flux



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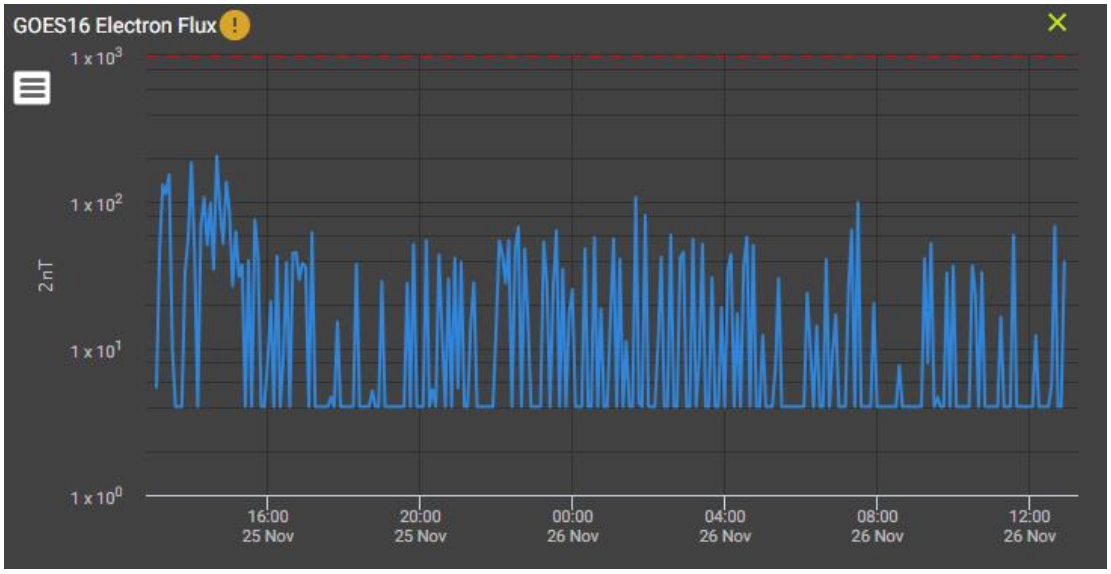
High Energy Electrons Event (≥ 2MeV):

Electron flux levels have been at Background levels following the arrival of the CME from early 22 Nov, as well as any HSS connection. This suppression in electron flux is expected to persist through the first half of the forecast period, given combined forecast CME and HSS (CH75/+) influences on the electron belt and geomagnetic activity in the coming days. High levels of election flux may be reached Day 3 (28 Nov) or Day 4 (29 Nov) when there is an increasing chance that the reduction in the solar wind pressure following recent CMEs and high-speed streams could allow the Van Allen belts to relax and electron flux at GEO to subsequently increase. However for this to occur on Day 3 this relies on possible glancing blow CME on Day 2 missing Earth.

Fluence levels are expected to remain below the 1e8 Active threshold throughout the period. The Met Office REFM model forecast will not account for the recently observed, nor the forecast, CME arrivals, and therefore will likely indicate higher fluence values than should be observed. A rising trend in the Recurrence forecast between Days 1 and 2 (26-27 Nov) is based on an earlier arrival time of the high-speed stream from CH75/+ and subsequent recovery of the electron belts on the previous solar rotation. Any notable rise is not expected to take place until Day 3 (28 Nov) or later.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	5	20	30
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: GOES 16 Electron flux and fluence



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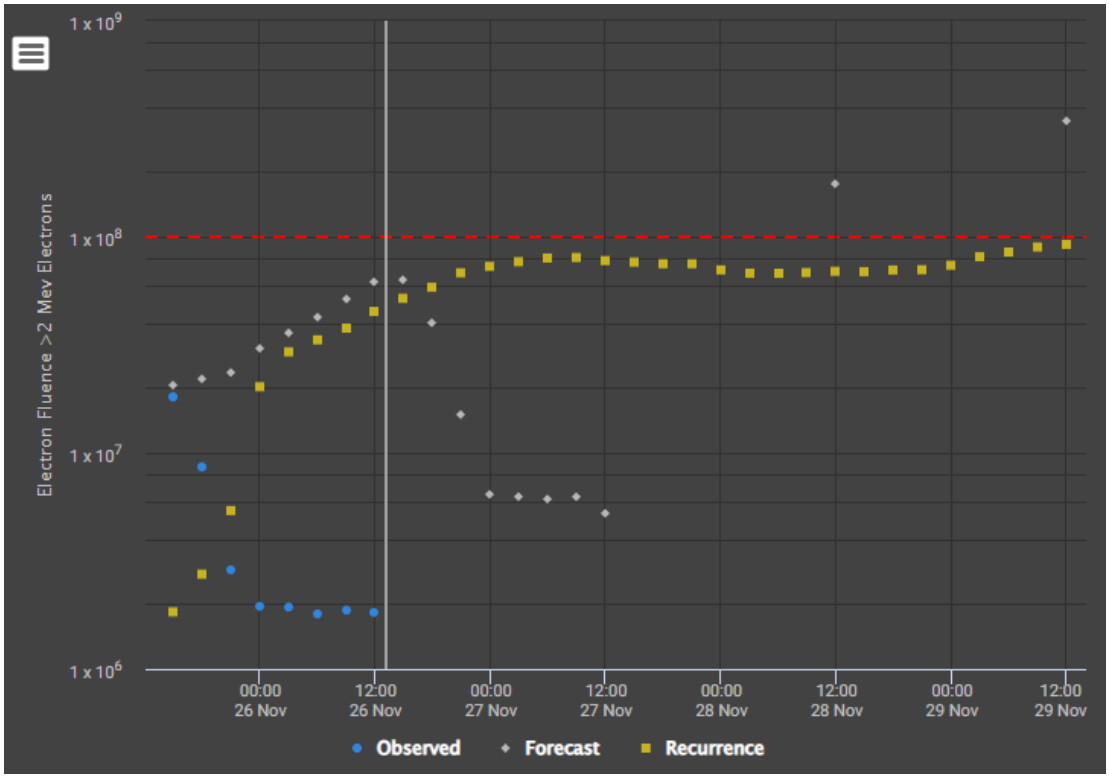

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